NICARAGUA

ARAP

Agriculture Reconstruction Assistance Program

TROPICAL FRUIT AND SPICES PROJECT

Lychee and Longan in Nicaragua

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EXECUTIVE SUMMARY

Efforts are being made to increase agricultural production in northern Nicaragua, especially in areas affected by Hurricane Mitch. A project supported by Chemonics Inc., USAID, World Relief and *Pueblos en Acción Comunitaria* (PAC) is importing a range of tropical fruit trees and spices for evaluation as potential crops for domestic and export markets. Key species in this study include the tropical fruit lychee and longan. It is hoped to replace some of the sites currently under coffee with these crops, as well as plant them in new areas.

Nicaragua has suitable climates and soil for cultivation of both lychee and longan, especially at elevated sites. A range of cultivars should be imported for propagation and evaluation in the different areas.

Lychee and longan originated in the area between southern China, Viet Nam, Burma and Malaysia. Lychee has been distributed to many areas of the tropical and subtropical world, whereas longan is only well known in South-East Asia. Lychee is most popular in China, Viet Nam, Thailand and India, with these countries accounting for more than 75 percent of world production. In contrast, longan is only significant in China, Viet Nam and Thailand. Neither industry is well established in Central or South America, with a few commercial plantings in Florida and Mexico.

Most of the commercial lychee and longan industries are found in warm subtropical areas, or at elevation in the tropics. Nights generally fall below 20°C or 10° to 15°C in winter at the time of flower initiation. This period is generally dry, with rainfall below 100 millimetres during the three months proceeding flowering. There are a few exceptions to this pattern with small tropical lychee and longan industries in Central Thailand, which account for about 10 percent of Thai production. A tropical longan industry is also important in southern Viet Nam in the Mekong Delta, with these plantings accounting for more than 80 percent of the Vietnamese industry. Some of the cultivars here may crop twice a year.

There are many hundreds of lychee and longan cultivars around the world, although commercial production is generally limited to less than a dozen in most countries. The majority of commercial lychee cultivars are based on selections from China, although there are a few local selections in Thailand, Viet Nam, India and Australia. Within longan, most of the commercial cultivars come from China and Thailand. The Thai ones are generally considered to have better marketing appeal. There are also a few tropical ecotypes from southern Viet Nam.

Normally temperatures below 20°C induce flowers. Flowering is irregular at higher temperatures, with the exception of a few tropical ecotypes in Thailand and Viet Nam. A short drought in winter may assist flowering, especially in the more tropical types, but is not essential. Annual rainfall of 1200 to 1500 millimetres is probably required in the absence of irrigation. An extended drought during fruit development will invariable reduce returns. This will limit lychee and longan production to wetter areas in Nicaragua. The other critical part of the crop cycle is fruit set that is reduced when temperatures fall below 20°C for extended periods during flowering. Persistent cloud cover at this time can also be a problem. This could be a concern at higher mountain areas such as Matagalpa.

Trevor Olesen (see Menzel, Olesen and McConchie, 2000) developed a model showing the relationship between potential flowering of lychee with latitude along eastern Australia. This was related to the number of days per year with mean temperatures below 20°C. This model can be used to estimate the reliability of flowering at different elevations instead of latitude in Nicaragua. These can be derived by estimating the change in mean temperature with elevation, using a base temperature for Managua which is close to sea level: mean temperatures fall by about 0.6°C for each 100-metre rise in elevation. Once mean temperatures for the coldest month are determined, estimates can be made of flowering at different elevations in Nicaragua.

The Pacific and Caribbean coasts are too warm for traditional lychee and longan production. Areas with elevations of 1200 to 1400 metres or so appear suitable for traditional subtropical cultivars. Higher areas should be avoided if temperatures fall below 20°C during flowering, or if there is extended cloud cover such as Matagalpa and Las Sabanas. This could also be a problem in the northern areas near Honduras such as Jalapa. There are many areas suited between Matagalpa and Jinotega, and further east between Wiwili and San Jose de Bocay. Unfortunately, there is no distinct plateau where these crops could be grown under extensive cultivation.

More tropical lychee cultivars such as those from Central Thailand could be planted at lower elevations down to 800 metres. The true tropical longans will probably crop at lower elevations (eg. Chinandega). Not all areas at these elevations will be suitable because of irregular rainfall during flowering and early fruit set. For instance, Esteli has suitable temperatures for lychee flowering, but is probably too dry for consistent production without supplementary watering. Areas with annual rainfall of 1200 to 1500 millimetres are suggested. Many sites have a substantial water deficit where evaporation from a Class A pan exceeds rainfall for several months of the year. For instance, it is quite dry from December to April in Chinandega, and dry from December to May in Jinotega.

The agricultural soils of Nicaragua are generally fertile and well drained. Lychees and longans are adapted to a wide range of soils, including acid and alkaline soils. Production is generally only limited at extremes of soil pH when there are problems with trace nutrients such as iron. Soil type is not likely to restrict production in Nicaragua, provided well-drained sites are used.

The suggested lychee cultivars to import include Kom, along with Chacapat from Thailand, Fay Zee Siu, Tai So (Mauritius) (both from China), Kwai May Pink (an Australian selection) and Wai Chee (China). These plants are all available from Australian nurseries. For longan, potential cultivars include Chompoo, Haew and Biew Kiew from Australia, along with Daw and Phetsakon from Thailand, and Longnhan and Tieuhue from Viet Nam.

There are certain issues which need to be addressed in the tropical fruit nurseries. These include over-watering of many of the lychee and longan introductions, improvements in the grafting of the avocado material, and provision of shade for the mangosteen plants. Many of the young trees (eg. peach) planted at the different sites also need some form of pruning to improve tree structure and shape.

Many tropical fruit and spices are being evaluated in this project. However, there could be difficulties marketing some of them, because of the lack of infrastructure and ready access to

the market in Managua. Perishable fruit such as lychee, longan and rambutan need to be marketed quickly as they lose moisture soon after harvest.

Quarantine issues also need to be resolved for some of these crops since they are considered host for Caribbean fruit fly by the USA. These problems could be overcome by exporting fruit to Europe, although there could be problems with lack of airfreight between Central America and most European destinations. This issue probably also affects trade between Central and North America. Many of these crops are also slow to come into bearing (especially mangosteen and cashew). Faster growing crops such as passionfruit should be considered in the warmer areas. There are also opportunities for growing cash crops such as potato which are currently imported by Nicaragua.

The temperate fruit market is well established in the USA and parts of Europe. The industries are well established, with well-developed fruit quality standards. Apples, peaches and strawberries from Nicaragua would face strong competition. In contrast, very few subtropical and tropical fruit are grown in the USA, with only small industries in Florida (apart from Citrus). These have the best potential for exports. Within the group, lychees are probably more popular.

RECOMMENDATIONS AND KEY FINDINGS

1. Nicaragua has suitable soils and climates for commercial lychee and longan production. Both subtropical and tropical cultivars can be grown.

2. The Pacific and Caribbean coasts are too warm for traditional production. Areas with elevations of 1200 to 1400 metres or so appear suitable for traditional subtropical cultivars. Higher areas should be avoided if temperatures fall below 20°C during flowering, or if there is extended cloud cover (eg. Matagalpa and Las Sabanas). This could also be a problem in the northern areas near Honduras (eg. Jalapa). There are many areas suited between Matagalpa and Jinotega, and further east between Wiwili and San Jose de Bocay. Unfortunately, there is no distinct plateau where these crops could be grown under extensive cultivation.

3. More tropical lychee cultivars such as those from Central Thailand could be planted at lower elevations down to 800 metres. The true tropical longans will probably crop at lower elevations (eg. Chinandega). Not all areas at these elevations will be suitable because of irregular rainfall during the some months. For instance, Esteli has suitable temperatures for lychee flowering, but is probably too dry for consistent production without supplementary watering. Areas with annual rainfall of 1200 to 1500 millimetres are suggested.

4. Only cultivars that are readily accessible are described, with the emphasis on subtropical ecotypes. Thus, the suggested lychee cultivars to import include Kom along with Chacapat from Thailand, Fay Zee Siu, Tai So (Mauritius) and Wai Chee from China, and Kwai May Pink from Australia. Longan cultivars for evaluation include Chompoo, Haew and Biew Kiew from Australia, along with Daw and Phetsakon from Thailand, and Longnhan and Tieuhue from Viet Nam. Most of these plants are available from Australian nurseries.

5. Many marketing issues need to be resolved before these crops are widely grown in Nicaragua. These include problems with road infrastructure and ready access from the mountains to Managua. There are also quarantine issues with fruit susceptible to Caribbean fruit fly marketed in the USA, and freight access to North America and Europe.

6. The market for traditional summer fruit such as apple, peach and strawberry is well developed in the USA and very competitive. Marketing of these fruit from Nicaragua will not be easy. Of the tropical fruit, lychee is more popular than longan and rambutan. Mangosteen is too slow growing to be a strong candidate for tropical fruit expansion in Nicaragua. Faster growing alternatives such as passionfruit and potato should be considered. Information on growing these crops is available from Australia.

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INTRODUCTION AND BACKGROUND

Pueblos en Acción Comunitaria (PAC) is an association founded in 1994 supported by World Relief/Nicaragua. It is a small producer/rural women's association with over 5,000 members. PAC's aim is to work with World Relief to increase agricultural production, processing and marketing within Nicaragua. World Relief through its partners is undertaking emergency rehabilitation after hurricane Mitch including agricultural restoration in Madriz, Esteli, Nueva Segovia and Jinotega funded by USAID. Chemonics, a consultancy company based in Washington and PAC are collaborating with World Relief in these activities.

There is an expanding tropical fruit market in Central America, especially with rambutan which are exported from Honduras to neighbouring countries. There are promising markets for spices as well. The region is now ready to embark on trade in exotic fruits and expand production of spices. Once these crops are in production in Nicaragua, export opportunities will be addressed. Three tropical fruit nurseries have been established in Las Sabanas, Wiwili and San Jose de Bocay to propagate mangosteen, rambutan, pulasan, lychee, longan, durian, and banana. Spices include cinnamon, cloves, nutmeg, and black pepper. There are also some temperate fruit such as apple, peach, strawberry and blackberry to be evaluated at elevation.

The focus of the project is in northern Nicaragua, much of which was affected by Hurricane Mitch. Sites were chosen to give a range of climates and elevation. For instance, Las Sabanas is a high elevation, high rainfall, cool subtropical location; Wiwili is a low elevation, medium rainfall, tropical location; Plan de Gramma is a high altitude, high rainfall, warm subtropical location; while San Jose de Bocay is a humid, low to medium elevation, high rainfall, tropical location.

ARAP (Restoration of Agriculture in Nicaragua) has identified market opportunities for the exotic fruit lychee and longan, although little technical experience exists in Central America in these crops. Information is required on suitable cultivars, growing areas and agronomy if these two crops are going to be commercialized successfully. In this report, the performance of different cultivars was related to elevation, minimum temperatures in winter and annual rainfall. Suggested growing areas and cultivars for importation are provided.

GEOGRAPHY AND WEATHER OF NICARAGUA

Merrill (1993) and Anonymous (2001) provide a description of the different landforms and their impact on weather in Nicaragua. These data can be used to estimate the relative production of lychee and longan and other crops in different areas.

Nicaragua is divided into three major regions: tropical lowlands along the Pacific coast, central cooler highlands and tropical lowlands along the Caribbean coast. Along the Pacific, a stretch of low, hotland lies between the ocean and the two major lakes - Nicaragua and Managua. A chain of volcanoes, many of them active, rises along the length of the coastline. This fertile area produces sugar. Farther inland the landscape rises to plateaus of more than 450 metres. The country's highest mountain range, the Cordillera Isabella, crosses the area, containing peaks of 2,100 metres. The lower areas of these highlands produce cattle, and the higher areas coffee, the nation's major export crop. About half of the country consists of the eastern lowlands, known as the Mosquito Coast. There were once extensive stands of tropical hardwoods, but most have been cut. Tropical rain forests grow between rivers that empty into the Caribbean. Bananas are grown along river valleys, but elsewhere, soils are generally poor.

Temperature varies little during the year in Nicaragua and is largely a function of elevation. The *tierra caliente* or "hot land," is characteristic of the foothills and lowlands up to about 750 metres. Here, days average 30° to 33°C, and nights drop to 21° to 24°C most of the year. The *tierra templada* or "temperate land," is characteristic of most of the central highlands from 750 and 1,600 metres. Here, days are mild (24° to 27°C), and nights cool (15° to 21°C). *Tierra fría*, the "cold land" above 1,600 metres, is found only on the highest peaks of the central highlands. Average maxima are 22° to 24°C, with lows below 15°C.

In contrast to temperature, rainfall varies greatly in Nicaragua. The Caribbean lowlands are the wettest part of Central America, receiving 2,500 to 6,500 millimetres of rain annually. The western slopes of the central highlands and the Pacific lowlands receive considerably less, being protected from the Caribbean trade winds by the peaks of the central highlands. Precipitation for the rift valley and western slopes of the highlands ranges from 1,000 to 1,500 millimetres. Rainfall is seasonal - May through October is wetter, and December through April drier.

During the rainy season, eastern Nicaragua is subject to heavy flooding along the upper and middle reaches of all major rivers. The coast and some other areas are also subject to destructive tropical storms and hurricanes, particularly from July through October. In 1988 and 1994, Hurricanes Joan and Mitch were particularly destructive.

AGRICULTURE IN NICARAGUA

Since the colonial period, Nicaragua's economy has been based on the export of raw materials, largely agricultural products. Coffee has been a major crop since the 1840s, with cotton, sugar, banana, forestry, mining, cattle, and shrimp also contributing to the economy. The economy grew rapidly from 1950 to 1980, as agricultural exports and industry expanded, but has declined in recent years (Merrill, 1993; Anonymous, 2001). Agricultural products including coffee, cotton, banana, sugar and beef dominate exports valued at US$581 million in 1998. Agricultural workers account for 28 percent of the country's actively employed population (Merrill, 1993; Anonymous, 2001).

Large-scale coffee growing began in the 1850s, and by 1870 coffee was the principal export, a position it held for the next century. Coffee is a demanding crop, however, because the trees require several years to produce a harvest, and the entire production process requires a greater deal of land, capital and labor compared with many other crops. Coffee grows only on the rich mountain soils, making transportation to the market difficult. In 1992, more land was planted under coffee than for any other crop. The actual amount of land devoted to coffee varies from year to year, but averaged 210,000 hectares in the 1980s. Production is popular in the central highlands near Estelí, and also in the hilly areas around Jinotepe. Production totalled 67,860 tonnes of raw beans in 1999. Nicaragua's poor transportation system and ecological concerns over the amount of land devoted to growing crops on volcanic slopes in the Pacific region limit further expansion. Growers have begun to explore other crops in undeveloped areas of the country.

Unlike the rest of Central America, bananas are not a major export earner. They were introduced in the 1880s, but political turmoil and difficulties in establishing secure transportation hampered exports. Because United States companies developed production in neighbouring countries, the potential for this crop remaines undeveloped. Disease outbreaks and the keeping quality of many cultivars also limits expansion. Production is centered in the Pacific lowlands from Ago de Managua to the Golf de Fiances. Production in 1989 was 132,000 tonnes.

Although much of lowland Nicaragua has a climate conducive to growing sugar, poor transportation has limited production to roughly the same area where bananas are grown. Production of raw sugar stood at 2,300 tonnes in 1989.

ECOLOGY OF LYCHEE PRODUCTION

The lychee (*Litchi chinensis*) which belongs to the Sapindaceae or soapberry family originated in southern China and possibly in northern Vietnam and the Malay Peninsula. Lychee trees grow wild in abundance on Hainan Island near northern Vietnam mainly at an elevation of 600 to 800 metres, and below 500 metres in hilly areas in Le izhou Peninsula, in the west of Guangdong and the east of Guangxi. Wild lychees are a major species in several lowland rainforest areas on Hainan Island and may account for 50 percent of the virgin forest composition.

The lychee was introduced to the tropical and subtropical world from the end of the 17th Century. Large commercial industries have developed in China (1,000,000 tonnes), Taiwan (200,000 tonnes), India (500,000 tonnes), Thailand (50,000 tonnes), Vietnam (40,000 tonnes), Madagascar (50,000 tonnes) and South Africa (15,000 tonnes). There is substantial interest in the crop in Australia, Mauritius, Reunion, Spain, Nepal, Bangladesh, Israel, Mexico and The United States.

Lychees are grown commercially from 17° to 30° latitude, and are usually found at low elevation in the subtropics and from 300 to 600 metres in tropical locations, with cool or cold winters and warm to hot summers. Rainfall is generally highest in summer and least in winter or spring. There are a few exceptions to this pattern such as Cairns in northern Australia (latitude 17°S) where they are grown along the coastal flats and in some areas of South Africa (latitude 25°S) where they are found at 600 to 800 metres. In both these locations, winters are dry and the Tai So or Mauritius cultivar is grown. Production is very erratic for many cultivars in coastal northern Queensland, but more consistent at elevation in South Africa.

There is a small industry in the Philippines at 1000 to 1400 metres where nights fall below 20°C, with a few orchards at lower elevation in Batangas and Laguna. Tropical lowland types have also been developed for the central plains of Thailand north of Bangkok and in a few selected areas of Indonesia. There are small lychee industries in Israel and Spain that have a typical Mediterranean climate with cold wet winters and hot dry summers. The range in climates in the main production areas is much narrow for lychee compared with other tropical fruit such as citrus and banana that are grown across several climatic zones. There are no commercial cultivars that will flower and fruit under tropical lowland conditions, where the nights never fall below 20°C. This is in contrast to longan, where there are tropical industries in Thailand, Viet Nam and Indonesia .

Most of the lychee growing areas have winter minima below 20°C and usually below 15°C or 10°C. Winters are usually dry with rainfall of less than 25 millimetres or between 25 and 50 millimetres. Temperatures below 20°C and cloud cover during flowering can reduce fruit set. Most orchards in South-East Asia are under dryland conditions. Annual rainfall of about 1200 to 1500 millimetres usually provides sufficient moisture for cropping. A few weeks of drought in winter may assist flower initiation, however drought at other stages of the growth cycle can reduce yield or fruit quality. Well-grown trees can have roots below 1.5 metres. This can help the trees buffer short-term droughts. Good protection from wind is also essential for cropping.

POTENTIAL LYCHEE CULTIVARS FOR NICARAGUA

The lychee has undergone intensive selection in China and is reported to have more cultivars than any other fruit tree. It is reported that the first book on tree fruits in China was devoted to a description of lychee cultivars. The main cultivars in southern China are Souey Tung, Haak Yip and Wai Chee, followed by Tai So, Sum Yee Hong, Chen Zi, Kwai May, Fay Zee Siu and No Mai Chee. Production in other countries is based on Chinese cultivars selected under Chinese conditions: Haak Yip in Taiwan; Tai So, Haak Yip and Wai Chee in Thailand; Tai So in South Africa; and Tai So and Bengal (from India), Kwai May (Pink) and Wai Chee in Australia. Kwai May Pink dominates the industry in Australia, and accounts for more than 60 percent of plantings. It performs well in both southern and northern areas.

The only exception to this pattern is in India and Central Thailand where local selections of Chinese imports are exploited. Most of the Indian cultivars are similar to Tai So and Bengal, with relatively large seeds. Some of the cultivars from the more tropical areas of Thailand such as Kom may have a role at lower elevation in Nicaragua. However, these cultivars only contribute only a little to Thailand's production, which is mainly based in the northern hills. There is also a late-season large-fruited cultivar called Chacapat that is worth considering. Unfortunately its performance in Australia has been disappointing, with fruit a little sour at harvest. There are promising selections from low elevation in the Philippines such as UPLB Red (University of the Philippines at Los Banos) and Olan which was imported as a seed from Thailand.

Tree, branch and leaf characteristics, fruit maturity and fruit characteristics such as size, shape, skin color, type of protuberances, seed size and aroma, taste and texture of the flesh can distinguish cultivars. A description of potential cultivars for Nicaragua is provided below.

Kom is one of lychee cultivars developed locally in Thailand from cultivars imported from China. It is reported to crop under warm subtropical conditions, but fruit quality is poor to average. Kom has been imported into Australia, but has not been distributed elsewhere. Planting material is not readily available. Fruit mature about a week before Tai So. Fruit are variable in size, shape and flesh recovery depending on the season. Fruit tend to be small in southern Queensland when cool spring weather extends into early summer. Although Kom is high yielding, its poor quality in southern Queensland limits its potential. It is not considered a good marketing type in Australia because of its small fruit and poor flavor. However, it appears to perform better in Thailand where it is the dominant warm season lychee.

Chacapat is grown in Thailand and has been recently imported into Australia. It is the latest maturing lychee cultivar in both areas. Fruit are normally very large, but acidic under most conditions in Australia. Cropping ability in Australia is average. In some seasons, when cool spring weather extends into summer, trees may set mostly small fruit with small seeds. Chacapat is not considered a good marketing type in Australia, but seems to perform well in northern Thailand. It is considered one of the best lychee cultivars in the area around Chiang Mai.

Fay Zee Siu is ranked as one of the best lychees in China, and is in great demand for export. It has been recently imported into Australia. It is grown in and around Guangzhou. Fruit mature early in the season before Tai So. The tree is vigorous with long sparse fragile branches, and so must be pruned regularly. Production in Queensland has been somewhat

erratic, certainly less consistent than Kwai May Pink. It is grown mainly in northern Queensland where it fetches a high price with fruit on the market very early in the season. Fruit are large (24-32 g) and the flesh firm, sweet, delicious and very fragrant. Seed size is variable.

Tai So is a common cultivar in China, Thailand, South Africa, Australia, Florida and Hawaii where it is often called Mauritius. Yields tend to be low and irregular in all countries, with the exception of South Africa. Despite the low yields it is still grown in northern Queensland because it produces early in the season when market prices are strong. It can crop heavily some years. Its response to pruning after harvest is less predictable than other cultivars in Australia such as Kwai May Pink. Trees are very vigorous in tropical locations. Trees in warm locations also tend to produce too few female flowers to guarantee successful fruit set. Trees are vigorous and spreading with an open crown. The branches have weak crotch angles and are susceptible to splitting. Even large trees may suffer wind damage. Fruit is not of good quality until fully mature. Flavor is sweet acid when immature and sweet when fully ripe, becoming bland when overripe. There are usually very few chicken tongues (8 to 12 percent), although in some seasons (cool spring weather) there may be up to 50 percent or more chicken tongues. Fruit also tend to split in hot weather and are susceptible to browning if they suffer water deficits.

Kwai May Pink is thought to have originated in China possibly as a variant or seedling of Kwai May Red. The cultivar has become popular in recent years in Australia and large numbers of trees have been planted. Bearing ability is good in most districts. It has a long harvest period, possibly due to the development of acceptable sweetness and flavor well before full maturity. Many fruit are small seeded. Fruit are harvested mid-season.

Wai Chee is the most common cultivar in China (especially in Guangxi) and is also popular in Thailand and Australia. It is considered to be a reliable cropper and to have wide adaptability, although it does not crop heavily along the coastal strip in northern Queensland unless winters are cool. Fruit hang on the tree for up to 14 days after reaching maturity, which allows some flexibility in harvesting as well as extend ing the production season. Trees establish slowly after planting and lack vigor. Trees require regular pruning and fertilizing to maintain production.

Only cultivars that are readily accessible are described, with the emphasis on subtropical ecotypes. Only Thailand has a significant “tropical” industry that is based on the cultivar “Kom”. Thus the suggested cultivars to import include Kom, along with Chacapat, Fay Zee Siu, Tai So (Mauritius), Kwai May Pink and Wai Chee. These plants are all available from Australian nurseries. There are also sources in Thailand and Viet Nam which are listed in a later section of this report.

ECOLOGY OF LONGAN PRODUCTION

The longan (*Dimocarpus longan*) also belongs to the Sapindaceae or soapberry family from tropical Asia and is closely related to the lychee. It is similar in growth and fruiting habit. The tree is tougher and less demanding with respect to climate and soil conditions than lychee, however, the exact environmental requirements for cropping of both species have not been adequately defined.

The longan originated in subtropical China or possibly in the area between Burma and India. Wild longan trees have been found growing on Hainan Island amongst the rainforest. It reached

Thailand in the late 19th century and Hong Kong, Hawaii and Florida by the early to mid-20th century. Despite its wide environmental adaptation, the longan is a commercial crop only in four countries, i.e. China (600, 000 tonnes), Taiwan (150,000 tonnes), Thailand (250,000 tonnes) and Vietnam (365,000 tonnes).

Longans rate number 12 in order of total production for tropical fruits in Thailand with an average of 12 to 15 times more longans produced than lychees. This may in part be due to the poor bearing of lychee in Thailand compared to longan. Longan production is centred in the subtropical monsoon areas of Chiang Mai, Lamphun and Prae (300 metres above sea level), the Chiang Rai region at 600 metres, the Fang region at 550 metres and scattered throughout the area between Chiang Mai and Fang (80 percent of production). It also includes some areas in the central plains north from Bangkok. The quality of the fruit is better in the northern areas compared to the central and north-eastern regions.

In China, Fujian, Guangdong and Guangxi dominate longan production, with the longan more important in the cooler subtropical areas of Fujian. Within Fujian, longans are second in importance only to citrus.

Longans are adapted to tropical and warm subtropical areas with high rainfall. They grow and crop best in areas with short cool frost-free winters and long hot humid and wet summers. The temperature regime for fruit set and development is similar to that for lychee, but, the minimum temperature required inducing panicle and flower initiation appears to be less. The minimum temperatures for flowering in northern Thailand are 15º to 20ºC, or preferably 10º to 15ºC. The tropical ecotypes, however can flower at much higher temperatures. In near equatorial areas at low elevation such as Ho Chi Minh City (latitude 11ºN; elevation 9 metres), minima do not fall below 20ºC during the year.

Longans survive drought periods, but production is adversely affected without irrigation in dry environments. The average rainfall in longan - growing areas in southern China and Thailand exceeds 1000 to 1500 millimetres. However, most of this rain is distributed during the period of late fruit growth in summer. The monsoon normally commences after flowering and early fruit growth and finishes before the period of bud burst after harvest. Consequently, the best dry land yields in China and Thailand are obtained on trees growing on alluvial soils with access to the water table. Yields are usually highest when 1200 to1400 millimetres of rain falls during March to June. Drought during the flower and fruit drop period in March and April can reduce yields substantially.
It can thus be concluded that the best yields for longan will occur in areas with winter minimums below 15º to 20ºC, except for tropical cultivars that can flower at much higher temperatures. Rainfall of at least 1200 to 1500 millimetres is required under dryland conditions. A short dry period in winter may assist flowering, however, drought during the rest of the crop cycle should be avoided.

POTENTIAL LONGAN CULTIVARS FOR NICARAGUA

There are over 300 to 400 longan cultivars with about 30 to 40 cultivated commercially. This is possibly because of the long history of longan and the propagation of the crop by seed. China has the most cultivars, however, many horticulturists maintain that the best forms come from Thailand. There have been a few cultivars produced from the USA (Homestead, Kohala), and more recently several ecotypes out of Viet Nam which crop regularly in the Mekong Delta.

There are few other tropical types from Thailand, Malaysia and Indonesia. Some of these tropical types along with the better cultivars from Thailand are worth importing and evaluating in Nicaragua.

Longan cultivars are relatively uniform and it can take sometime to become familiar with the different cultivars. Nevertheless, they vary with respect to tree size, shape and canopy density, leaf size, color and arrangement, bark characteristics, yielding ability, disease and wind resistance and fruit size, flesh recovery and eating quality. The fruit of some cultivars will hang on the tree after reaching satisfactory maturity without loss of quality. Some cultivars are best eaten fresh, others are more suitable for drying or canning. The demand is for large-fruited cultivars with high flesh recovery, crisp sweet flesh and good flavor.

Other important characteristics for longan cultivars are regular and heavy yields and long season (for each cultivar in a region). Good shelf life and processing characteristics are also desirable. Biennial bearing and small seed size have been the major obstacles in breeding and selection. Good fruit size and heavy cropping are not mutually exclusive. However, many of the small-fruited types in China, Thailand and Florida are heavy yielding.

Nearly all longan cultivars originated from southern China or were developed from progeny of Chinese cultivars. Thai cultivars are usually more highly regarded, fruit being larger, sweeter in flavor and crisper in texture. A description of potential cultivars for Nicaragua is provided below.

The most popular cultivars in Thailand, in order of maturity are Daw (Early), Dang (Red Seed), Chompoo (Pink), Haew (Water Chestnut), Biew Kiew and Baidum (Black Leaf). There is also many thin-fleshed seedling types (Tammada, meaning common) which are often high yielding, but marketed at lower prices.

Daw is the most popularly grown cultivar in Thailand accounting for 80% of production, and is also the most consistent bearer. This is in contrast to its behavior in Australia where it sets very poorly. Fruit are large with a big seed, thin skin and crisp sweet flesh and generally good flavor (some fruit may have a sulphur smell). Fruit do not keep well on the tree and the seed may even germinate. Dang is similar to Daw in productivity and quality (more juicy). Fruit are large with corresponding sized seed. Quality of the fruit deteriorates once they are mature. Trees are susceptible to waterlogging.

Chompoo has large fruit (in long clusters) with small seed and is of excellent quality. The flesh is slightly pink after processing and is therefore suitable only for fresh eating. Cropping is not as regular as Daw or Dang, mainly because of poor flowering. This cultivar requires high fertility and good management to yield heavily.
Haew has large fruit with firm flesh and excellent eating quality. Fruit should be tree-ripened for best flavor. The fruit stalk is hard and hence difficult to fold for packing. However, the post-harvest life of Haew is good because its thick skin reduces water loss. Fruit are suitable for canning. The main shortcoming of Haew is its alternate bearing habit.

Biew Kiew is highly regarded in Thailand, but is slow to come into production and some types are irregular yielding. Fruit are large with good flesh recovery, crisp dry creamy colored flesh and excellent quality.

Thus, the best quality cultivars in Thailand are Biew Kiew, Chompoo and Haew. Cropping regularity is greatest in Daw, followed by Dang, Haew, Chompoo and Biew Kiew. All these cultivars are now in Australia, with the exception of Daw that is different to the form in Thailand.

Thailand also has a tropical longan (Phetsakon) which is grown in the central region of the country in Samut Sakhon and Ratchaburi Provinces. However, the Thai industry is mainly based in the northern Provinces around Lamphun, Chiang Mai and Chiang Rai. The author has no information on the quality of this cultivar. There are also difficulties obtaining planting material from Thailand. Viet Nam has tropical cultivars that crop twice a year or produce three crops in two years (Longnhan and Tieuhue). It is not known if these cultivars are available for export. These cultivars are similar to "Diamond" which has been imported from Malaysia.

In summary, it is worth importing Chompoo, Haew and Biew Kiew from Australia, along with Daw and Phetsakon from Thailand, and Longnhan and Tieuhue from Viet Nam. Possible sources of this material are indicated in a later section.

AREAS SUITABLE FOR COMMERCIAL LYCHEE AND LONGAN PRODUCTION

The key factors to consider when assessing the potential of different areas for lychee and longan cropping are temperatures in winter which affect flower initiation, temperatures and light levels in spring which affect fruit set, and reliability of rainfall which affects fruit development. Many data have been collected in Australia on the relationship between reproductive growth in lychee and temperature. Normally temperatures below 20°C induce flowers, while flowering is irregular at higher temperatures, with the exception of a few tropical ecotypes in Thailand. Fewer data are available for longan, although the response appears to be similar. There are however, some true tropical types that will flower at temperatures above 20°C.

A short drought in winter may assist flowering, especially in the more tropical types, but is not essential. Annual rainfall of 1200 to 1500 millimetres is probably required in the absence of irrigation. An extended dry period during fruit development will invariable reduce returns. This will limit lychee and longan production to the wetter areas in Nicaragua.

The other critical part of the crop cycle is fruit set that is reduced when temperatures fall below 20°C for extended periods during flowering. Persistent cloud cover at this time can also be a problem. This could be a concern at higher mountain areas such as Matagalpa.

Trevor Olesen (see Menzel, Olesen and McConchie, 2000) developed a model showing the relationship between potential flowering of lychee with latitude along eastern Australia (Figure 1). This was related to the number of days per year with mean temperatures below 20°C. At lower latitudes (more tropical sites), there were few days suitable for flowering, while at higher latitudes (more subtropical sites), there were several weeks of suitable temperatures. These data are supported by the relative performance of mature trees in the different areas, with higher average production at Bundaberg, Nambour and Ballina than at Cairns. The data can be used to show the changes in mean temperature in July with latitude as well (Figure 2). You can then predict flowering in other environments if you have access

to temperature data (Figure 3), with a plot of likely flowering versus mean temperatures for the coldest month.

The model of Menzel *et al*. can be used to estimate the reliability of flowering at different elevations (instead of latitude) in Nicaragua. These can be derived by estimating the change in mean temperature with elevation, using a base temperature for Managua which is close to sea level (Figures 4 and 5). McAlpine *et al*. (1983) used a similar model to derive changes in temperature with elevation in Papua New Guinea. Other models are available, but they are generally similar, with temperature falling by about 0.6°C for each 100-metre rise in elevation. Once mean temperatures for the coldest month are determined, estimates can be made of flowering at different elevations in Nicaragua (Figure 6). This analysis is dependent on the actual temperature at elevation being close to that predicted by the model. An examination of the data from five sites indicates a difference of ± 1.0°C between the predicted and actual temperatures (Table 1). The reliability of the model is confirmed. The Pacific and Caribbean coasts are too warm for traditional lychee and longan production. Areas with elevations of 1200 to 1400 metres or so appear suitable for traditional subtropical cultivars. Higher areas should be avoided if temperatures fall below 20°C during flowering, or if there is extended cloud cover such as Matagalpa and Las Sabanas. This could also be a problem in the northern areas near Honduras such as Jalapa. There are many areas suited between Matagalpa and Jinotega, and further east between Wiwili and San Jose de Bocay. Unfortunately, there is no distinct plateau where these crops could be grown under extensive cultivation.

More tropical lychee cultivars such as those from Central Thailand could be planted at lower elevations down to 800 metres. The true tropical longans will probably crop at lower elevations (eg. Chinandega). Not all areas at these elevations will be suitable for lychee and longan because of irregular rainfall during spring. For instance, Esteli has suitable temperatures for lychee flowering, but is probably too dry for consistent production without supplementary watering. Areas with annual rainfall of 1200 to 1500 millimetres are suggested for Nicaragua. Many sites have a substantial water deficit where evaporation from a Class A pan exceeds rainfall for several months of the year (Figure 7). For instance, it is quite dry from December to April in Chinandega, and dry from December to May in Jinotega.

The agricultural soils of Nicaragua are generally fertile and well drained. Lychees and longans are adapted to a wide range of soils, including acid and alkaline soils. Production is generally only limited at extremes of soil pH when there are problems with trace nutrients such as iron. Soil type is not likely to restrict production.

Table 1. Weather data for different sites in Nicaragua. Data from David Bradford.

Site	Elevation (m)	Mean temperature in January (^{o}C)	Predicted mean temperature in January (^{o}C)	Mean temperature in July (^{o}C)	Annual rainfall (mm)
Chinandega	60	26.7	25.9	26.9	2513
Muy Muy	320	23.4	24.8	24.6	1598
San Isidro	430	24.5	24.2	25.6	777
Esteli	800	21.2	21.9	27.2	952
Jinotega	1032	19.5	20.8	21.4	1409

GENERAL COMMENTS AND SUGGESTIONS FOR FOLLOW UP

Nursery stock

There are three nurseries propagating a range of temperate, subtropical and tropical fruit plus a range of spices. Not all species seem to have a high rate of success. Only a few of the recent lychee and longan introductions at San Jose de Bocay seem to have survived. The plants appear to be overwatered, and are receiving 2 hours of irrigation each morning. A more frequent light watering (mist system) is recommended. The aim is to keep the leaves moist and stop the plants overheating. Under these conditions, the actual water use by the plants is quite low. The containers used are also too large, and are likely contributing to waterlogging. Five to seven litre long bags should be sufficient. Care must also be taken when potting up the young airlayers, as they have a very fragile root system at this stage. A light pruning of the shoots can also assist at this stage. Once the lychees and longans lose their leaves, they seldom recover.

There also appears to be some difficulty with propagation of some of the avocado material. Generally, this species is one of the easiest to bud or graft. In Australia, the young plants are normally kept under light shade initially, and the new bud covered with a plastic bag and a paper bag. These are removed after a few weeks when the new shoot starts to grow. Information on grafting of avocado is freely available from Australia.

The young mangosteen plants need to be grown under about 50% shade for optimum growth in the nursery. They are very slow growing, and will often die in full sun. Some shade during the initial field establishment stage would also be beneficial.

Care of young trees

The newly planted trees are generally well maintained in the different areas. However, many of the species would benefit by some form of pruning and tree shape. This is especially the case with the apple, peach and pear trees, but this also applies to some of the tropicals. Once again this information is readily available from Australia. Watering is also very critical during this stage, although not all sites have permanent irrigation.

Potential of different crops in Nicaragua

The expansion of fruit growing in Nicaragua is to be applauded, however, there are certain constraints. Nicaragua has a range of ecosystems, and has the benefit of several areas of elevation, although no true plateau. Thus a range of fruits from temperate to true tropical can be grown. There are also large areas of fertile agricultural soils. Rainfall is highest and more regular on the Caribbean Coast, whereas some of the western and central areas of the northern Provinces can have long dry periods. This needs to be considered when planning new fruit orchards. There are also difficulties with the infrastructure in some areas that will make marketing of perishable fruit such as lychee, longan and rambutan difficult. These areas are perhaps more suitable for processing crops such as coffee.
The main crops under study include subtropical apples and stonefruit, strawberries and raspberries, subtropical fruit such as lychee and longan, and the tropicals rambutan and

mangosteen, along with a few spices. There is an expanding market for most of these crops within Central America, including Nicaragua, however there could be difficulties with some of these crops into North America and Europe. The temperate fruit market is well established in the USA and parts of Europe. Apples, peaches and strawberries from Nicaragua would face strong competition. The industries are well established, with well-developed fruit quality standards.

In contrast to the temperate fruits, very few subtropical and tropicals are grown in the USA, with only small industries in Florida (apart from Citrus). These have the best potential for exports. Within the group, lychees are probably more popular. Mangosteens are not well known in most of North America and Europe. They are also unlikely to return a profit for many years after planting, because they are slow growing and take at least ten years to bear a commercial crop. Quicker growing alternatives should be considered. These industries will also be dependent on regular airfreight out of Central America. There is also a problem in that some of these fruit are considered a host of Caribbean fruit fly for entry into the USA.

Both the yellow and yellow x purple hybrid passionfruit should be considered as possible crops for low and medium elevations. These species are easy to grow, and provide a quicker return than some of the fruit trees. The industry could be based on fresh fruit as well as processing. They are well regarded throughout most of Central and South America. There is also a potential market with passionfruit pulp exports to the USA. Potato is another crop that should be considered for some of the warmer areas. Information on suitable cultivars and agronomy is readily available from Australia.

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TERMS OF REFERENCE

1. Survey the proposed lychee and longan production activities in the Mitch-affected area. Look at technology levels, agro-climatic factors, cultural practices, and producer group capabilities.

2. Recommend sites for the procured varieties. To date PAC has procured the lychee varieties Mauritius and Joaquin, and the longan variety Diamond Riviera.

3. Identify knowledge gaps in production, harvesting and post-harvest management among PAC beneficiaries and potential growers and recommend improved practices.

4. Provide ongoing technical assistance to the producer groups assisted by ARAP and PAC.

F.

5. A report detailing major recommendations and findings, including requirements for each variety, focusing on appropriate different geographical zones and areas within these zones for each variety. These will be condensed into production guides which will be distributed to growers, NGOs and other interested organizations.

6. Identify additional regional and extra-regional sources of planting materials available for the production activity, and if required assist PAC and ARAP in their procurement and shipment to Nicaragua. This would include a report on varieties available in Florida, Hawaii, Honduras, Australia and Thailand. This would be done in case of availability of varieties that are better suited to the PAC zones. These could then be procured with additional PAC funds.

7. At least one ARAP/PAC sponsored public presentation on lychee and longan production in the Hurricane Mitch-affected zone, and a smaller one in Managua.

ITINERARY

July 21. Travel from Maroochydore/Sydney/Los Angeles.

July 22. Travel from Los Angeles/San Salvador/Managua.

July 23. Managua. Meet with staff from Chemonics and World Relief.

July 24. Managua/Esteli/Las Sabanas/Palacaguina. Visit grape, tomato, bean, coffee processing, tropical and temperate fruit nurseries.

July 25. Wiwili. Visit tropical fruit nursery, and spices.

July 26. San Jose de Bocay. Visit tropical fruit nursery and plantings including lychee, longan, rambutan, coffee and spices.

July 27. Miaflora. Visit temperate fruit including strawberry, raspberry, apple and stonefruit.

July 28. Managua Report preparation.

July 29. Managua.

July 30. Leon/Chinandega/Corinto. Visit tropical fruit including banana, plantain, papaya, pineapple and cashew.

July 31. Esteli/Somoto/Las Sabanas. Visit grapevines, coffee and temperate fruit.

August 1. Ocotal/Diplito/San Fernando. Visit pine forests, coffee and temperate fruit.

August 2. Matagalpa/Jinotega/Sebaco. Visit subtropical fruit, flowers, strawberries, potatoes, onions and other vegetables.

August 3. Esteli/Santa Cruz. Visit potatoes, vegetables and herbs.

August 4. Managua. Report preparation.

August 5. Managua.

August 6. Managua/Esteli. Report preparation.

August 7. Esteli. Presentation.

August 8. Travel Managua/San Salvador/Los Angeles.

August 9. Travel Los Angeles/Sydney/Maroochydore.

G. APPENDIX 1

Linn. Syst. Nat. 13: 602 & 635 (1791)

***Litchi chinensis* Sonn**

SAPINDACEAE

2n = 28, 30 or 32

Synonyms. *Nephelium litchi* Cambess. (1828) *Dimocarpus litchi* Lour. (1790)

Vernacular names. lychee or litchi (En); litchi (Sp); litchi (Fr.); Li Zhi (China)

Origin and geographical distribution. The lychee originated in the area between southern China, northern Vietnam and Malaysia. Wild trees are still found growing in both elevated and low rainforests and in some parts of southern China and Hainan Island, lychee is one of the main forest species. Lychee has a long history in southern China and has undergone intensive selection. It was cultivated by people of Malayan descent long before the Chinese moved that far south. The lychee has been distributed to most of the tropical and subtropical world in the last 400 years. The spread of lychee to other countries has been slow due to the exacting climatic requirement of this species, as well as the short life of its seed.

Uses. Lychees are cultivated for their very popular fruit and have a long history of acceptance in China and many parts of South East Asia. The demand is for large bright red fruit with small seeds and crisp sweet flesh. China, Taiwan and Thailand have substantial canning industries. Not all cultivars are suitable for canning. Some cultivars develop an "off flavor" with heat sterilization which many western palates find objectionable. A large proportion of the crop in China was traditionally dried as "dried lychee nuts", and this is the form that many people are familiar with. However, the present destination of the crop is: 60% fresh, 20% canned and 20% dried. Lychee fruit can also be processed into pickles, preserves, ice-cream, yoghurt, juice and wine.

World production. The main producing countries are China (61820 t), Taiwan (131000 t), Thailand (8401 t), India (91860 t), Malagasy Republic (35000 t), South Africa (5687 t), Mauritius (1000 t), Reunion (1000 t) and Australia (1000 t). There is also interest in the crop in Vietnam, New Zealand and the USA. Production in southern China is centered in Guangdong and Fujian where lychee ranks either 2nd or 3rd behind citrus and longan as the most important fruit crop. Thailand and Taiwan exported about12 000t of lychee to Singapore and Hong Kong in 1984. About 2000t of fruit are also exported to Europe, mainly from South Africa, Mauritius and Reunion.

Properties. The food value of lychee lies in its sugar content which ranges from 7 - 21%, depending on climate and variety. Lychee fruit also contain about 0.7% protein, 0.3% fat, 0.7% mineral (particularly Ca and P) and are reasonable sources of vitamins C (64 mg/100g pulp), A, B_1 and B_2.

Description The lychee is a large (25m tall) long-lived evergreen tree with a short stocky trunk. In some cultivars the branches are crooked or twisting, and low hanging and spreading forming a head broader than high. In other cultivars, the branches are fairly straight and more or less upright, forming a compact rounded head. Leaves are alternate, pinnately compound with 2 - 5 pairs of leaflets and generally about 7 - 28 cm long. The blades of the leaflets are soft and a lustrous deep green on the upper surface and a waxy lighter green (glaucous) on the under surface. The leaflets are normally elliptical to lance - shaped.

The inflorescence is a many branched panicle which, depending on cultivar varies in length from 5 cm to over 30 cm. It bears hundreds of small yellow white flowers which are basically male (only stamens well developed) or hermaphrodite

and either effectively female (stamens small, anthers not dehiscing) or male (undeveloped ovary). The proportion of different flower types varies with cultivar and temperature conditions during flower differentiation.

The typical one-seeded fruit may be round, ovoid or heart-shaped depending on the cultivar. The fruit skin is thin, leathery and bright red in most cultivars. It is rough in appearance, being covered with angular conical protuberances. The fleshy edible portion of the fruit is called an aril or arillus and is an outgrowth of the seed stalk. In highly prized cultivars, the aril completely covers the seed and may comprise 70 - 80% of the fruit weight. The aril is white and translucent and has a consistency of a prime muscat grape. Seeds are 10 - 23 mm long and 6 - 12 mm wide and are chestnut brown in color. In some cultivars, a high proportion of the seeds in fully developed fruit may be abortive (small and shrivelled). These abortive seeds are called "Chicken tongue" seeds. Fruit with abortive seeds are preferred, since they contain a greater proportion of flesh.

Growth and development. Trees propagated by air-layers (marcots) usually produce commercial crops after 3 - 6 years. High-yielding trees follow a distinct pattern of vegetative growth, flowering and fruiting. Flowering and hence cropping are eliminated if vegetative growth continues in the 1 - 2 months before floral induction in winter. Excessive vegetative is a problem in several countries (eg. Australia, northern Thailand, Guangdong Province, Florida and Hawaii). Vegetative growth occurs as a series of flushes alternated with periods of dormancy. The duration of flushing and the interval between successive flushes are reduced at high temperatures (25 - 30^{o}C) and constant water supply.

The normal pattern of development in high - yielding trees is 2 - 3 months of vegetative growth after harvest in mid-summer followed by a period of dormancy 1 -2 months before panicle emergence in early winter. Panicle and flower development continues for 6 - 12 weeks after floral induction without a period of flower dormancy. Fruit set in spring normally lasts 4 - 6 weeks for a single cultivar at any one location. Fruit are ready for harvest after 11 - 16 weeks.

Botanical relations. Two other subspecies of *Litchi chinensis* are recognized: *subsp. philippensis* from high altitudes in the Philippines and *subsp. javensis* from Malaysa, Indonesia and parts of Papua New Guinea. *Litchi chinensis subsp. javensis* has fruit which are similar to the cultivated lychee and is grown in gardens of Malaysia. However, neither subspecies is cultivated commercially.

The lychee has undergone intensive selection in China and is reported to have more cultivars than any other fruit tree. It is reported that the first book on tree fruits in China was devoted to a description of lychee cultivars. The main cultivars in southern China are Souey Tung, Haak Yip and Wai Chee, followed by Tai So, Sum Yee Hong, Chen Zi, Kwai May, Fay Zee Siu and No Mai Chee. Production in other countries is based on Chinese cultivars selected under Chinese conditions: Haak Yip in Taiwan; Tai So, Haak Yip and Wai Chee in Thailand; Tai So in South Africa; and Tai So and Bengal (from India), Kwai May (Pink) and Wai Chee in Australia. The only exception is in India where local selections of Chinese imports are exploited. Cultivars can be distinguished by tree, branch and leaf characteristics, fruit maturity and fruit characteristics such as size, shape, skin color, type of protuberances, seed size and aroma, taste and texture of the flesh.

Ecology. The lychee is one of the most environmentally sensitive of the tropical

tree crops. It is adapted to the tropics and warm subtropics (between 13° - 32°N and 6° - 29°S), cropping best in regions with winters that are short dry and cool (daily max. below 20-22°C) but frost free and summers that are long and hot (daily max. above 25°C) with high rainfall (1200 mm) and high humidity. Good protection from wind is essential for cropping.

Propagation and planting. Air-layering is the main commercial method of propagation and rates of success are usually not less than 95%. Other methods of propagation include grafting, budding and cutting. These methods are useful for top working older trees with new cultivars or for the rapid multiplication of new cultivars but can be slow to establish in the field. There are problems of incompatibility with some scion/rootstock combinations.

Spacings of 6 x 6 m (equivalent to 280 trees/ha) are possible with upright lychee cultivars such as Kwai May Pink and to a lesser extent Wai Chee. More vigorous cultivars such as Tai So, Souey Tung and Haak Yip can be planted at 9 - 12 m between the rows and 6 m between trees (equivalent to 140 - 185 trees/ha). Erect cultivars planted at 6 x 6m spacings need to be thinned out at year 10 - 12 (140 trees/ha) and again at the year 14 - 16 (70 trees/ha). Vigorous trees require thinning at year 8 to 10 at 9 - 12 x 6 m (70 - 90 trees/ha).

Husbandry. Lychees are normally grown with irrigation. The only exception is in China. The water supply to the trees is managed to maintain vegetative dormancy during the 2 to 3 months before emergence of the flowering panicle in winter. Water management is far more easily controlled in dry areas and on light soils with low water holding capacity. Water is applied at high rates to prevent moisture stress from the emergence of the panicle, during flowering, fruit set, fruit growth and after harvest during the summer flush. Tensiometers installed in the major root zone are useful in determining the timing and amount of water to apply.

Fertilizer management is also directed to limiting trees to only one vegetative flush after harvest and to maintaining dormancy in winter. This can be achieved by maintaining leaf N below 1.5-1.8% before floral induction. Once the trees have flowered, every effort should be made to keep a high proportion of the flowers and fruit on the panicles. To meet the desired control, fertilizer is applied at flower panicle emergence and after fruit set. Other times are also mentioned in China and South Africa (before and after harvest). Suggested amounts for well-grown 5-year-old trees are 200 g N, 80 g P and 300 g K/year increasing to 500 g N, 170 g P and 700 g K/year at year 10 and to 1000 g N, 300 g P and 1400 g K/year at year 15. The rate and form of fertilizers can be determined with the use of leaf and soil analysis, together with a visual estimate of vegetative vigor, size of bloom, leaf color and fruit yield. Leaf nutrient standards for lychee have been developed form healthy high yielding trees in Australia: 1.5 - 1.8% for N; 0.14 - 0.22% for P; 0.70 - 1.10% for K; 0.60 - 1.00% for Ca; 0.30 - 0.50% for Mg; 50 - 100 µg/g for Fe; 100 - 250 µg/g for Mn; 15 - 30 µg/g for Zn; 10 - 25 µg/g for Cu; 25 - 60 µg/g for B; < 500 µg/g for Na; and < 0.25% for Cl. Leaves are collected just after panicle emergence. Recommended rates of macronutrients/m^2 tree ground cover are: 4 g borax, 4 g copper sulphate, 5 g manganese sulphate, 10 g iron sulphate, 25 g zinc sulphate and 40 g magnesium sulphate. Foliar applications usually only increase leaf levels for a few months because of growth dilution and limited plant uptake.

Cincturing has been used commercially in China, Thailand, Australia, Florida and Hawaii to induce an artificial dormancy in

winter and improve flowering and fruiting. Trees are cinctured at the completion of the post-harvest flush of growth, about 2 to 3 months before panicle emergence and 5 to 6 months before flower opening. Trees should be healthy and vigorous, and be flushing actively after harvest.

The general response to lychee trees to any form of pruning is to fill the gaps with vigorous less fruitful foliage as quickly as possible. Excessive pruning at harvest time or at any other time during the year is to be discouraged. Young trees are pruned to form a good shape in the first few years. Older trees are skirted and thinned internally after harvest every 2 - 3 years to improve structure against wind damage.

Pests and diseases. No major disease currently limits lychee growing. A parasitic algae (*Cephaleuros*) occasionally attacks trees causing loss of vigor. Cultivars such as Souey Tung and Haak Yip are very susceptible. Control is with two sprays of copper, before and after the wet season. A slow decline and a sudden death have been recorded in southern Queensland, especially in poorly drained soils. *Armillaria* occasionally attacks roots and the base of trees of any age causing death or slow decline. The fungus may survive in soil or stumps and roots of various trees for many years.

Nematodes are known to be a problem in South Africa and three species (*Xiphinema*, *Paratrichodorus* and *Helicotylenchus*) have been associated with tree decline in Australia. Attack by these species can result in considerable root damage. However, the exact role played by nematodes on tree decline is not yet clear. Experiments in South Africa with post-plant nematicides have shown considerable promise. Basically, the pest complex affecting the crop is the same in different countries, with some differences in the relative severity of some of the pests in different environments. Erinose mite (*Eriophes litchii*) is the major pest of the foliage. Severe infestations may damage developing flowers and fruit, and kill the growing points. Erinose mite can be very difficult to eradicate once an infestation is established. Dipping lychee air layers in dimethoate helps prevent the introduction of the mite into orchards. Red-shoulder beetles (*Monolepta australis*), leaf rolling caterpillars (*Platypeplus aprobola* and *Isotenes miserana*) and scales (*Chloropulvinaria psidii*) occasionally attack lychee trees but can be controlled with currently available insecticides. Several flower caterpillars (*Phycita leucomilta, Lobesia spp*. and *Prosotas spp*.) attack developing panicles and flowers. One or two sprays of methomyl during the season give effective control. Other insect pests which sometimes cause economic damage at flowering include red shoulder beetles, thrips and rutherglen bugs. The main insects affecting fruit are fruit spotting bug (*Amblypelta nitida* and *A. lutescens*), lychee stink bug (*Lyramorpha rosea* or *Tessaratoma papillosa* in China), macadamia nutborer (*Crytophlebia ombrodelta* or in its equivalent in China (the lychee moth, *Acrocercops crameralla*) or South Africa (the lychee moth, *Argyroploce peltastica*), elephant beetle (*Xylotrupes gideon*) and fruit piercing moth (*Othreis fullonia* and *Eudocima salaminia*). The first two mentioned species caused the loss of young fruit. The other species may also cause fruit to drop prematurely. However, the main economic loss is the deterioration of damaged fruit after harvest. Chemical control is available only for fruit spotting bug, lychee stink bug and macadamia nut borer. Birds and flying foxes can cause serious damage in Australia, Thailand and South Africa some seasons.

Harvesting. Lychees do not ripen off the tree. Unripe fruit may sweeten a little, but do not develop full flavor. Maturity is judged by a particular shape, skin color, skin texture and flavor of each cultivar. A

maturity index based on sugar/acid ratio has been developed in Australia. Most fruit can be picked from a tree within 1 week and from a single cultivar in an orchard within 3 weeks. Most growers plant a range of cultivars to spread the picking workload. Clipping too much leaf and wood with the panicle can reduce flowering in the next season. In most parts of Asia, fruit are marketed on the panicle after blemished and insect-damaged fruit are culled. However, in Australia, South Africa and the USA fruit are clipped from the panicle. Grade standards based on size, color, blemish and uniformity of quality have been developed in Australia.

Yield. Average yields for a 10 year old tree in southern Queensland range from about 10 to 50 kg/tree in an irregular bearing cultivar such as Tai So to 30 to 80 kg/tree for a regular bearing cultivar such as Wai Chee. These yields are equivalent to 0.7 to 11.2 t/ha at recommended spacings. Yields of 10 t/ha are possible in well-managed orchards in Guangdong. Average yields are about 2 t/ha. Lychee is considered a poorer proposition in Fujian.

Handling after harvest. Lychees in Asia are marketed in 22 - 25 kg bamboo baskets, normally without any refrigeration or post-harvest treatment to maintain shelf life and are consumed within 3 days of picking. Lychee fruit lose their bright red skin color and turn brown within a few days after harvest. Browning is faster under low humidity conditions. Efforts to maintain humidity tend to cause post-harvest rots to develop. To prevent browning and rotting, Australian growers dip fruit in 0.5 g benomyl/L solution at 52^{o}C for 2 min. This treatment is particularly important for fruit not refrigerated on farm. Punnet packs with PVC overwrap are used is Australia and allow lychees to be displayed to the consumer without excess browning. The film retains sufficient humidity to inhibit browning without condensation clouding the pack. Storage at 5 - 8^{o}C can prolong shelf life of treated fruit by 4 - 6 weeks, depending on the cultivar.

Genetic Resources. Most of the world's production is based on Chinese selections selected under Chinese conditions. Consequently the genetic diversity of cultivated lychee is narrow. Wild lychees are found growing in parts of southern China, Vietnam, Malaysia, the Philippines and Papua New Guinea but there have been few attempts to collect this material. Collection of commercial cultivars are held at several places in southern China and also at Research Institutes in Taiwan, Thailand, India, South Africa, Australia and the USA. Successful crosses between the lychee and the longan (*Euphoria longan*) were reported in the 1920's in China. Fruit were not exceptional.

Breeding. Most cultivars have been developed from open - pollinated seedlings. More recently there have been attempts in Taiwan and Australia to cross pollinate cultivars with specific characteristics. Most breeding programs have been limited to small plantations, usually not exceeding 200 - 500 plants. The industry in southern Thailand is based on local selections of Chinese cultivars which will crop under tropical conditions. However, the fruit quality of these selections does not match that of the Chinese cultivars. A few cultivars have also been bred in Florida (Peerless from Brewster) and Hawaii (Groff and Kaimana from Haak Yip) in the last 50 years, but only Kaimana warrants further attention. Priorities in a lychee breeding program include: regular high yields, large fruit size, bright red skin color, small seed size, high eating quality, and acceptable ripening and storage characteristics.

Prospects. Lychee production is expanding most rapidly in the smallest producers eg. Australia, South Africa and the USA, where there is strong demand for

exotic fruits and fruits with export potential. In the traditional growing countries of Asia production is easily outstripped by local demand, but expansion is limited by available horticultural land. A rapid expansion of production is also expected in the next few years where new plantings in Vietnam, Malagasy Republic, Mauritius and Reunion come into bearing. Many countries in southern America and southern Africa have large tracts of land which would be suitable for lychee production.

Several factors favour the expansion of lychee: trees are easily propagated and grow on a range of soil types; the fruit are normally available for 4 - 5 months in any one country if different environments are available; the fruit has a high value for long distance transport; the fruit can be processed into a wide range of products; the fruit is well known in Asia and is highly regarded in western Europe; fruit can be identified by cultivar to obtain premium prices in export markets; orchard has a long life. However, there are some attributes which may limit the expansion of lychee: low environmental adaptability of some cultivars, trees moderately susceptible to environmental stresses; high cost of harvesting and marketing in some countries; fruit require dipping and cool storage for long post-harvest life; poor image of canned fruit; fresh product not well known in some western countries; lack of buyer confidence in fruit quality in some markets; and trade barriers to export fruit (Japan and USA).

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Source. Menzel, C. M., (1991). Litchi. In *Plant Resources of South-East Asia Vol. 2. Edible Fruit and Nuts* (E. W. M. Verheij and R. E. Coronel, Eds.). Pudoc, Wageningen, The Netherlands. pp. 191-5.

H. APPENDIX 2

Dimocarpus longan Lour.

Fl. Cochinch. : 233 (1790).
SAPINDACEAE
2n=30

Synonyms. ssp. *longan* var. *longan*: *Dimocarpus longan* Lour. (1790), *Euphoria longana* Lamk (1792) nom. illeg., *Nephelium longana* Cambess. (1829).

- ssp. *longan* var. *longepetiolulatus* Leenh.: *Euphoria morigera* Gagnep. (1950) nom. inval.
- ssp. *longan* var. *obtusus* (Pierre) Leenh.: *Euphoria scandens* Winit & Kerr.
- ssp. *Malesianus* Leenh. var. *malesianus: Nephelium malaiense* Griff. (1854), *Euphoria cinerea* Radlk. (1878) nom. illeg., *Euphoria malaiensis* Radlk. (1879) nom. illeg., *Euphoria gracilis* Radlk. (1913) nom. illeg.
- ssp. *malesianus* Leenh. var. *echinatus* Leenh.: *Euphoria nephelioides* Radlk. (1914) nom. illeg.

Vernacular names. ssp. *longan* var. *longan:* longan (En). Longanier, oeil de dragon (Fr). Indonesia, Malaysia: lengkeng. Burma: kyet mouk. Cambodia: mien. Laos: lam nhai, nam nhai. Thailand: lamyai pa. Vietnam: nhan.

- ssp. *longan* var. *obtusus:* Thailand: lamyai khruer, lamyai tao.
- ssp. *malesianus* var. *malesianus*: Malaysia: mata kucing (Peninsular Malaysia and Sabah), isau, sau, kakus (Sarawak). Indonesia: buku, ihau (Kalimantan), medaru (Sumatra).

Origin and geographic distribution. Ssp. *longan* var. *longan:* Whereas some authors limit the area of origin to the mountain chain from Burma through southern China, others extend it to south-west India and Sri Lanka, including the lowlands. The crop is mainly grown in southern China, Taiwan and north Thailand with small acreages elsewhere in Indo-China as well as Queensland (Australia) and Florida (United States) and scattered trees at higher elevations in South-East Asia.

Ssp. *longan* var. *longepetiolulatus*: southern Vietnam.
Ssp. *longan* var. *obtusus*: Indo-China, cultivated in Thailand.
Ssp. *malesianus* var. *malesianus*: all over Indo-China and Malesia, greatest variation found in Borneo.
Ssp. *malesianus* var. *echinatus:* Borneo and the Philippines.

Uses. Longans as well as the minor fruits of the species are mainly eaten fresh. There are substantial canning industries for longan in Thailand, China and Taiwan. Large fruits are used, preferably those with small seeds. Fruit can be canned in its own juice with little or no sugar, due to the high level of soluble solids. Canned longans retain their individual flavor better than do rambutan or lychee. Longans can be preserved dry, either intact or after removal of the pericarp. The dried flesh is black, leathery and smoky in flavor and is used mainly to prepare a refreshing drink. A liqueur is made by macerating the longan flesh in alcohol. The seeds are used as a shampoo, like soapberries (*Sapindus saponaria* L.), because of their saponin content. Both the seed and the fruit flesh of longan have several medicinal uses. The leaves, which contain quercetin and quercitrin, and flowers are sold in Chinese herb markets. The red, hard longan timber and the fairly hard, light brown to yellow 'mata kucing' timber are useful, but rarely available. In eastern Thailand ssp. *longan* var. *obtusus* is grown as an ornamental climber.

Production and international trade. Longan production in Thailand was 20100 t in 1986/1987 and 58660 t the following year – showing the prominent tendency to biennial bearing – from an area estimated to be 23500 ha. The exports of fresh, canned and dried fruit, mainly to Singapore, Hong Kong and the European

Community, were 10600, 2950 and 0.4 t respectively in 1986. Elsewhere in South-East Asia only East Java produces an appreciable quantity of longan. The other fruits, such as 'mata kucing', are found in their season in some local markets only.

Properties. The edible portion of export quality fruit of 3 cultivars ranges from 67 to 78% of the whole fruit. Composition of longan per 100 g edible portion is: water 72.4 g, protein 1.0 g, fat 0.5 g, carbohydrates 25.2 g, fibre 0.4 g, ash 0.5 g, Ca 2 mg, P 6 mg, Fe 0.3 mg, vitamin A 28 IU, vitamin B_1 0.04 mg, vitamin B_2 0.07 mg, niacin 0.6 mg and vitamin C 8 mg. The energy value averages 458 kJ/100 g. The sugar content is very high. The composition of 'mata kucing' fruit is not very different, but carbohydrates – and energy values – are much lower, whereas much higher figures are given for mineral content.

Description. Tree, up to 40 m tall and 1 m trunk diameter, sometimes buttressed, exceptionally a scandent shrub; branches terete with 5 faint grooves, sometimes warty lenticellate, rather densely ferruginous tomentose. Leaves 2-4 (-6)-jugate, axial parts mostly densely hairy; petiole 1-20 cm, petiolules 0.5-35 mm long; leaflets elliptical, 3-45 cm x 1.5-20 cm, 1-5 times longer than wide, chartaceous to coriaceous, above often tomentose is basal part of midrib, beneath thinly tufted-tomentose mainly on midrib and nerves. Inflorescences usually terminal, 8-40 cm long, densely tufted-tomentose; cymules (1-)3-5 flowered; pedicels 1-4 mm; bracts patent, 1.5-5 mm long; flowers yellow-brown; calyx lobes 2-5 mm x 1-3 mm; petals 5, 1.5-6 mm x 0.6-2 mm, densely woolly to glabrous; stamens (6-)8(-10), filament 1-6 mm. Fruit drupaceous, 1-3 cm in diameter, lobe(s) broad-ellipsoid to globular, smooth to warty or sometimes up to 1 cm aculeate, sometimes granular, glabrescent, yellow-brown. Seed globular with shining blackish-brown testa; seed enveloped by a thin fleshy, translucent white arilloid.

Growth and development. Longan seeds are short-lived and best sown fresh. Germination takes 7-10 days. Seedling growth is slow and the juvenile phase lasts about 7 years. These characteristics also apply to 'mata kucing'. Logan trees grown from air layers come into bearing during the third or fourth year and yields tend to increase with tree size over a very long trajectory. Flowering within a panicle is a sequence of opening of staminate (pistil non-functional), pistillate (stamens non-functional), hermaphrodite and finally staminate flower again. Male and female phases of flowering overlap 4-6 weeks depending on cultivars. Pollination, by insects, is most effective between 8.00 a.m. and 2.00 p.m. In one study fruit set per panicle improved greatly with bloom rating for the tree, leading to a sharp progression in yield per tree (and an obvious risk of biennial bearing). The period from bloom to harvest is 5-7 months, depending on cultivar and climate. Longan in Thailand flowers just before or after the temperature rise at the end of the cold, dry season. Most fruit is harvested in August and September. In the panicles of 'mata kucing' male and hermaphrodite flowers occur. Flowering lasts only 1-2 weeks, the period varying from late June to mid-October in Sarawak. Pollination is mainly by insects such as ants, flies and honey bees (*Apis cerana, A. florea* and also *A. dorsata)*. Flowering is often prolific but fruit set is quite low and 2 weeks after flowering, when fruitlets measure 1 cm, many are shed. The fruit ripens about 4 months after bloom.

Other botanical information. The two subspecies and five varieties of *D. longan*, listed above, are distinguished mainly by differences in the leaflets. Within ssp. *malesianus*, var. *malesianus* shows the greatest variation in Borneo. The fruits are globular to slightly oblong and smooth to

warty. In Peninsular Malaysia, the most common form of this taxon is the one with globose smooth fruits which turn brown when ripe. This is the true 'mata kucing' and has usually been identified as *Euphoria malaiensis*. It has a very thin arilloid and is hardly worth eating. This form also exists in Borneo and Sumatra. The more superior forms are found in Sarawak, all with densely thick warty fruits and thicker arilloids. These forms can be roughly grouped into three types based on the fruit characteristics: the 'isau' with fruits which are globular and remain green when ripe, the 'sau' with fruits which are slightly oblong and also remain green when ripe, and the 'kakus' with globular fruits which turn brown when ripe. The leaves, flowers and tree forms also differ. The 'kakus' is more widespread in Sarawak, while the 'isau' and 'sau' are mainly confined to the river banks of the Rajang river and to the Bareo valley. Var. *echinatus* differs from var. *malesianus* in that the fruits have rather long spines resembling the rambutan (*Nephelium lappaceum* L.). This variety is found in Sabah where the 'kakus' also exists.

Three edible longan types are distinguished in Thailand, which presumably all belong to ssp. *longan*. The first one is a large forest tree with small fruits and a very thin aril, possibly of interest for breeding purposes. The second one is the common longan ('lamyai kraduk'), growing in the northern part of the country as an erect tree, producing small fruits with large seeds and is recommended as a rootstock for commercial cultivars. The third type is formed by the commercial cultivars ('lamyai kraloke') which produce large fruits and small seeds.

Important longan cultivars in Thailand are: 'Daw', 'Chompoo', 'Haew', 'Biew Kiew', 'Dang', 'Baidum', 'Luang' and 'Talub Nak'. In China 'Fu Yan', 'Wu Long Ling' (both in Fujian), 'Wu Yuan' and 'Shi Xia' (Both in Guangdong Province) are leading cultivars, in Taiwan 'Yong Tao Ye' and "Chiau On Diao'.

Ecology. Longan is a subtropical tree that grows well in the tropics but requires a prominent change of seasons for satisfactory flowering. A short (2-3 months) but cool (mean temperature 15-22°C) winter season brings out a prolific bloom; in this respect longan is less demanding and more predicable than lychee. From fruit set onwards high temperatures do not hamper development, but nights should not be warmer than 20-25°C. Ample solid moisture is needed from fruit set until maturity; suitable annual precipitation is about 1500-2000 mm.

Longan thrives on rich sandy loams, it does well on oolitic limestone; moderately acid sandy soils are more marginal and on organic muck soils flowering is deficient, probably because shoot growth continues for too long. In northern Thailand longan orchards are often situated on the lighter soils along former river courses, a ribbon of trees winding between the sawahs. The roots grow down 2-4 m to the water table.

The 'mata kucing' thrives in the humid tropical lowlands near sea-level, within about 10°C from the equator. The trees occur mainly in the substage or understorey in primary or sometimes secondary forests. Rainfall ranges from 2500 mm to more than 4000 mm per year associated with a mean air temperature of 25-30°C and a relative humidity of 65-95%. In Sarawak, the trees grow on alluvial soil, often on river banks. In other areas the trees grow on a wider range of soil types. A pH range of 4.5-6.5 is common in this region.

Propagation and planting. In Thailand longan are propagated through air layering, in China through approach

grafting using seedlings of the same cultivar as rootstocks. In the rainy season air layers root in 2-2.5 months; they are nursed in the shade for 6-12 months after separation. Trees obtained by air layering are more susceptible to wind than grafted trees; therefore either they are supported by permanent bamboo props, by soil mounded around the trunk, or rooted seedlings are planted close to the young tree and inarched to improve stability. Cuttings and budlings are rarely used. Tree spacing ranges from 6 m x 6 m to 12 m x 12 m; the latter spacing may also be the end result of thinning of the stand. There is a trend towards closer spacing; regular bearing would help to limit tree size to fit spacings of 6 m x 8 m to 7 m x 10 m.

'Mata kucing' and the other minor crops are commonly raised from seed, though clonal propagation through air layering is not difficult. Seed viability can be prolonged for some time by treatment with a fungicide and keeping the moisture level of the seed above 30%; desiccation is fatal. Rootstocks can be budded using the modified Forkert method, but slow and uneven budbreak remains a problem. For orchards the trees may be spaced 10 m x 10 m, in a square or hexagonal pattern.

Husbandry. Young longan trees are pruned to limit the number of main branches. In bearing trees harvesting is a form of pruning, since the entire panicle is cut. Soon after harvest this should be followed by cutting out some of the subtending twigs. Cutting out these twigs completely simplifies the canopy structure and admits more light to the interior of the tree; it also removes twigs that are least likely to fruit next year, since they have fruited this year. If this is not done side shoots emerge below the cuts of the harvested panicles. These shoots make the canopy more dense and come too late to initiate inflorescences for the next crop.

According to an old report grower in Fukien Province in China practise flower thinning in 'on' years. Since prolific bloom in longan, appears to be associated with heavy fruit set, the risk of over-thinning is small and as many as 50% of the panicles may be removed. Side shoots emerge below the cuts sufficiently early in the season to mature in time to initiate flowers for the next crop. Thus alternate bearing is suppressed by thinning.

Current pruning practice is mainly to remove suckers in the interior of the tree as well as branches that have lost vitality and panicles that remain after harvest; the skirt is maintained at a height of at least 1 m. These pruning practices do not restrict tree size.

Longans are rather exacting in their water requirements. Ample moisture is needed from flowering until shortly before harvest. Mulching is recommended and supplementary irrigation may be needed during this period. Once the trees become quiescent at the end of the growing season, rainfall may trigger a new flush of shoot growth, upsetting floral differentiation and resulting in failure of flowering.

There is no specific information on fertilizer requirements. Chinese work indicates that high yields are correlated with leaf nutrient levels as follows: N higher than 1.70%, P 0.12-0.20%, Mg 0.20-0.30%. Levels of 0.60-0.80% and 1.50-2.50% are recommended for K and Ca, respectively, but no relation to yield has been found.

For 'mata kucing' and related types husbandry is largely limited to harvesting and cutting back of the fruiting twigs.

Diseases and pests. The only disease of importance in longan in Thailand is rosette shoot or witches' broom, caused by a mycoplasm. Affected trees show abnormal growth and poor flowering. No cure is

known and affected trees should be grubbed out and burned. Powdery mildew infects inflorescences and young fruit of 'mata kucing' causing the same kind of damage as in rambutan. Thread blight occurs on branches and leaves of 'mata kucing'.

Numerous pests are found on longan. Of particular importance is the longan stink bug (*Tessaratoma javanica*) which can ruin bloom in a year with light flowering. There is also a flower-eating caterpillar. Chemical control interferes with pollination and the interests of bee keepers; the stink bug can be controlled by a hymenopterous parasitoid reared on silk-worm eggs. The fruit is attacked by piercing moths, borer caterpillars and fruit flies. Thai growers sometimes bag the panicles to protect them. The fruit – and that of 'mata kucing' c.s. – is also eaten by bats; a draconian control method is electrocution by a high screen of thin, parallel electric wires in the orchard.

Harvesting. Longan fruits, including the fruits of ssp. *malesianus*, are non-climacteric and have to be harvested when ripe. Maturity is determined by fruit shape, skin color and taste. Immature fruits are tasteless. The mature longan fruit has a dark, smooth skin, the inside of which is netted and tastes sweet. Longan trees should be picked twice at an interval of 7-10 days; 'mata kucing' fruit can all be picked in a single harvest. The whole panicle is cut with a knife or scissors. Panicles should not be dropped. They are sorted and bunched.

Yield. In Thailand the average longan yield ranged from 0.99-1.65 t/ha in 1981 to 1987. These average yields are extremely low when compared with well-kept orchards, which should produce up to 12 t/ha per year. For 10-15-year-old trees yields ranging from 60-190 kg/tree have been obtained. In East Java the very best trees produce 150-300 kg in a good year. Crops in Florida from trees 6 m tall and broad, have varied from light (22.5-45 kg) to medium (68-113 kg) and heavy (135-225 kg). The variation is largely due to alternate bearing.

Handling after harvest. Thai growers traditionally pack longan fruits with stalk intact in 35 cm x 50 cm round woven bamboo baskets containing 21-22 kg and lined with longan leaves. Fruit for export, often detached from the panicles, may be packed in corrugated boxes or plastic baskets. Since longan fruit have a high sugar content, they have a shelf life of a few days only at ambient temperature (25-31 ^{o}C). Longan fruit subjected to hydrocooling or forced air cooling can be stored at 5 ^{o}C for 40-45 days and at 10 ^{o}C for 20 days with a relative humidity of 85-90%. For long-term storage fruit can be fumigated with SO_2.

Genetic resources. Seeds are too short-lived for germplasm collection. Thailand has large tree collections of longan in Chiang Mai and Lamphun. The Thai cultivars differ in shoot, flower and fruit characters from the Chinese cultivars, but on the whole, genetic diversity appears to be narrow. There are several cultivar collections in Australia, the larges being a Kamerunga Horticultural Research Station near Cairns, Queensland. The University of Agriculture Malaysia with its branch campus at Bintulu, Sarawak, is now the largest collector of germplasm of *D. longan* ssp. *malesianus*. The great diversity in Sarawak offers a great opportunity to select superior material. Explorations in remote areas have been regularly made to identify trees with good quality fruit-thick flesh, fruit in consolidated panicles – and to collect budwood.

Breeding. Seedling progeny are extremely variable and small fruit size appears to be a dominant characteristic. Therefore through the centuries improved

cultivars have resulted merely from selection, in particular on large fruit size, high edible portion, crisp flesh, good flavor, and high sugar content. In so doing heavy and regular yields appear to have been sacrificed in comparison with the common longan in Thailand. Now marketing characteristics, such as early or late harvest, a long shelf life and a pure white aril for the canned product, must also receive more attention.

Prospects. Small fruit size and biennial bearing is the main constraint for expansion of the crop. The suggestions made above to ensure more regular bearing are based on piecemeal evidence, but they are simple to test. It is probably easier to attain good and stable yields of longan than of lychee; since these fruits substitute for one another this considerably enhances the prospects for longan. If threes bore regularly, growth would be moderated and it would be easier to prune to keep trees a manageable size. Small trees, coupled with closer spacing and regular yields would allow production to be intensified. The superior races of the spp. *Malesianus,* in particular the var. *malesianus* in Sarawak and other parts of Borneo, may offer an attractive alternative to longan for the humid tropical lowlands.

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Source. Wong Kai Choo and Saichol Ketsa (1991). Litchi. In *Plant Resources of South-East Asia Vol. 2. Edible Fruit and Nuts* (E. W. M. Verheij and R. E. Coronel, Eds.). Pudoc, Wageningen, The Netherlands. pp. 191-5.

APPENDIX 3

Lychee and longan in Australia

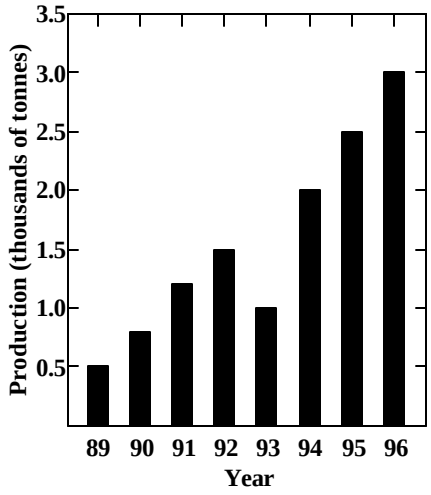
Introduction

The lychee (*Litchi chinensis* Sonn.) and longan (*Dimocarpus longan* Lour.) are members of the Sapindaceae family which includes the popular rambutan (*Nephelium lappaceum* L.). All produce delicious fruit containing an edible flesh from evergreen trees that will eventually grow to heights of greater than 20 meters. Lychee and longan are subtropical, although some cultivars will crop in the tropics at elevation. The largest producers of lychee and longan are China, Thailand and Taiwan. Lychees are also important in

India and Vietnam. Further expansion is occurring in these countries to meet demand generated by the increasing regional affluence.

Although lychee and longan were introduced to Australia more than 60 years ago, major commercial plantings only commenced in the 1970s. Currently, there are about 450 growers of lychee with production of 3000 tonnes worth $15M. Production has steadily increased over the past eight years (see Figure). Longan is considerably smaller with a value of about $2M, but also rising, especially with new plantings in northern Queensland.

Both crops are difficult to grow and yield consistently. The major production problems with lychee are irregular flowering and poor fruit retention, while in longan, alternate bearing and small fruit size reduce grower returns. Trees take three to five years to come into production, and will not produce substantial crops until year six or eight. They require regular chemical control measures for pests and suffer heavy losses to birds and fruit bats if not netted. The fruit only ripen on the tree and have a very short shelf life without refrigeration.



Successful lychee and longan production requires an experienced horticultural manager able deal with irrigation, tree nutrition and considerable pest load. You need to have an efficient packing and cool room facility as both crops deteriorates very quickly after harvest.

Australia has an advantage in the international market with production during the Northern Hemisphere "off season" including the lucrative Christmas and Chinese New Year festivities. Demand for high quality product far exceeds Australia's ability to supply. There are also opportunities in the domestic market, although some promotion and retail/consumer education are required.

Markets

There are approximately 500,000 tonnes of lychee and 300,000 tonnes of longans produced in Asia. Total production of lychee in the Southern Hemisphere is around 50,000 tonnes. In contrast, longan production is almost negligible.

In South East Asia, there is about 100,000 tonnes of longan and 25,000 tonnes of lychee traded as fresh fruit during the northern season. Longans are the most important fruit export from Thailand, with trade in the lucrative fresh fruit dominating, but fruit also canned or dried. The total value of this commerce is at least $50M. Trade is important and expanding in China, Taiwan and Vietnam. There is also about 15,000 tonnes of lychee exported to Europe from Madagascar and South Africa.

With longan in Thailand during the northern summer, early fruit may fetch from $3 to $5 per kg, but as supplies increase, the price drops to below $1 per kg. Returns for lychee are generally at least double those for longan. Out of season fruit from Australia during the northern winter would not necessarily achieve the high returns.

The bulk of Australia's lychee production is sold locally either at the farm gate or through the central markets, with about 30% exported. Exports have risen sharply in the past few years with improvements in post harvest handling and the development of co-operative marketing groups and quality assurance programs. These groups export about 60% of their production.

The main markets are Hong Kong, Singapore, French Polynesia, United Arab Emirates and the United Kingdom. Average net returns to the growers are about $5.50 per kg. This is after taking the costs of freight, commissions and agent's fees etc. At this stage the lucrative markets of Japan and the United States are not available due to quarantine restriction associated with lychee being considered a host of fruit fly.

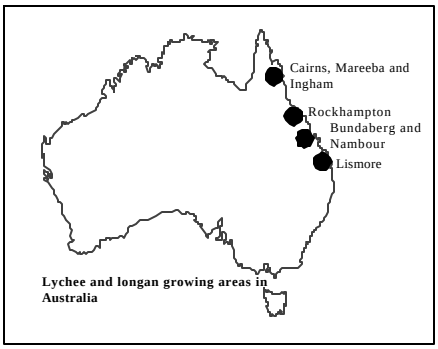
There have been trial consignments of longan fruit from northern Queensland to Hong Kong, but outturns have sometimes been disappointing. It can be concluded from these studies, that further research on storage temperatures, packaging etc is required if growers are to fully exploit this market. Average net returns to the growers were about $4.50 per kg, after taking into account freight, commissions and the extra costs of the plastic crates.

Production requirements

About 50% of production is in northern Queensland (Cairns, Ingham, and the Atherton Tablelands), 40% in central and southern Queensland (Rockhampton, Bundaberg, Gympie, Nambour and Caboolture) and only 10% in northern New South Wales. Longans are mainly found on the Atherton Tableland, with smaller plantings on the coast as far south as Byron Bay in northern New South Wales (see map).

The lychee season lasts from about early November in northern Queensland to about March in northern New South Wales. Longan generally matures about two months later.

Trees perform best on well-drained clay loam soils of medium to high fertility, with a minimum of one metre of well-drained topsoil. Trees may die on heavy clay soils which become waterlogged. There can also be problems on very sandy soils during hot weather in northern Queensland. Slopes greater than 15 percent are best avoided as they will not allow safe use of machinery for pest control, tree management, harvesting and may lead to erosion.



Lychee and longan growing areas in Australia

Lychee requires a period of cool weather (15^{o} to 20^{o}C) for successful flower initiation, but may be killed by frosts. Hot dry weather after fruit set has also been implicated in fruit drop, fruit browning and splitting. Fruit under these conditions do not develop full red color. Trees are also susceptible to wind damage, and should be protected by windbreaks.

Irrigation is normally required to produce commercial crops, but care must be taken with water quality. Water with an electrical conductivity of more than 600 to 1000 microsiemens per centimetre or dissolved salts of more than 500 parts per million may reduce productivity in lychee. It is generally considered that about two to four megalitres of stored water is required for each hectare of trees.

One person should be able to handle about five to seven hectares of mature trees without the need for other staff except during harvesting and packing. Depending on the yield and spread of cultivars, up to five to ten staff would be required for harvesting over summer. Basic equipment required would include: an under tree sprinkler irrigation system, tractor, sprayer, slasher or mower, trailer, harvesting equipment, netting and a packing shed and cold room.

You should talk to your local horticulturist to discuss the growing and marketing of these crops before your place orders for nursery plants. There is also valuable information in the *"Proceedings of the Lychee Seminar"* published every three to four years and in the Australian Lychee Growers' Association newsletter *"Living Lychee"*.

Cultivars

There are over forty cultivars of lychee and twenty for longan in Australia. However, the development of the industry has been hindered by lack of performance data for the major production regions. This has been accentuated by difficulties in identifying cultivars. Highest prices are paid for early and late fruit with strong skin color, firm flesh, aromatic flavor, high proportion of edible flesh and small seed.

Lychee cultivars currently being planted in northern Queensland on the Atherton Tablelands and coast include Kwai May Pink (Bosworth Number Three), Fay Zee Siu and Souey Tung, the later two being quite early. Kwai Mai Pink is also popular in central and southern Queensland and in northern New South Wales along with Salathiel, and the late cultivar Wai Chee.

The longan cultivars exploited are predominantly from Thailand and include Chompoo, Haew and Biew Kiew. The Hawaiian selection Kohala is also being planted because of its earliness and large fruit, but looses flavor under some circumstances. Biew Kiew is very late and may not mature before winter in northern New South Wales. Plants are available from commercial nurseries, but must be ordered at least six months in advance.

Agronomy

A well-managed orchard should have a long commercial life. Hence, close attention to orchard layout and land preparation will have their rewards for many years. You need to make decisions on row direction, spacings, placement of waterways and drains, mounding, wind protection and all weather access to the block. Your local horticulturist should be able to help you with the layout of your orchard are care of young trees. There is also details in the Queensland Department of Primary Industries Lychee Information Kit.

Plantings generally range from 100 to 300 trees per hectare. Recommended spacings are 12 metres x 6 metres for spreading cultivars such as Fay Zee Siu and Souey Tung (equivalent to 140 trees per hectare), and 6 metres x 6 metres for upright or low vigor cultivars such as Kwai May Pink, Salathiel and Wai Chee (equivalent to 280 trees per hectare). Internationally, higher density plantings have given greater returns, but these types of orchards are only experimental in Australia. There is little information available for longan, although the data for lychee could be used as a guide.

Tree rows are usually considered to best run north-south, but erosion and operator safety should be considered. Strong winds can seriously affect tree growth and production, so windbreaks need to be considered in most localities.

A soil analysis (including soil pH) before planting will indicate any potential nutrient deficiencies or imbalances which can be corrected. Discuss these results with your local horticulturist. Some soils may need an application of lime, phosphorus, nitrogen and some organic matter into the planting site. Many growers plant a manure or cover crop before planting and incorporate this organic matter into the soil to improve soil texture, fertility and orchard establishment.

Irrigation is generally considered essential for regular production in most of the commercial growing areas of eastern Australia, and is normally provided by under tree sprinklers. These systems can also be used to fertigate trees. In dry areas, the young plants will probably require watering at least weekly until they are well established.

Experiments have shown that drought has impacts on leaf growth, flowering, fruit development and quality in lychee, and similar responses would probably be shown for longan. However, in deep moisture retentive soils, it can take several weeks before drought has any impact on production.

Fertilizer management in lychee is currently based on the results of leaf and soil analyses collected annually in winter. During the early life of the orchard before the trees start to crop, it is recommended that the trees be fertilized about every three months. You will need to gradually increase the amount of fertilizer as the trees become larger.

Timing of fertilizer application generally has little impact on production. Most nutrients can be applied in two or three applications between flowering and harvest. The most likely nutrients to be low or deficient are nitrogen (N), potassium (K), magnesium (Mg), zinc (Zn), iron (Fe) and boron (B). In contrast, many orchards in Australia have excess amounts of phosphorus (P). There is little information available longan but following recommendations for lychee would be a good starting point. Information of the types of fertilizers to use can be obtained from your local produce agent.

Pest and disease control

Lychee and longan are subject to a wide range of pests which attack the tree, flowers and fruit. However, only a few of the regular pests affect production and need to be controlled. Your local entomologist will help you identify the major pests in your area. There are also consultants who will monitor pests in your orchard, advise on a spray program and help calibrate your sprayer.

Erinose mite (*Aceria litchi*) is a major pest of lychee and causes a brown felt like growth on the developing leaves, flowers and fruit. It can be very difficult to eradicate once established in an orchard. Recommended control is with three sprays of dimethoate or wettable sulphur at two to three week intervals to coincide with the elongation and expansion of new leaf flushes. New air-layers should be treated before they are planted.

Macadamia nutborer attacks both lychee and longan every season, and can devastate the crops. Larvae mainly develop in green fruit with significant seed development, but before there is a large amount of flesh. Sprays of azinphos-methyl need to be applied to coincide with the hatching of the oldest 10% of the eggs so that the newly emerged larvae will be killed before they enter the skin of the fruit. Effective control will probably require a minimum of two to three sprays. Flower caterpillars (*Lobesia* spp., *Isotenes miserana*, *Prosotas* spp. and *Phycita leucomiltra*) are major but occasional pests of lychee, which can be readily controlled

with endosulfan or carbaryl. Trees should be sprayed before the flowers open. The fruitspotting bug (*Amblypelta nitida*) and the banana spotting bug (*A. lutescens*) are common in southern districts, while the banana spotting bug is limited to central and northern Queensland. These bugs cause the developing green fruit to drop. Generally, lychees are less susceptible once the fruit have started to color, whereas longans can be attacked right up to harvest. Two sprays of endosulfan starting two weeks after fruit set will generally provide adequate control.

Adult fruit piercing moths (*Othreis fullonia* and *Eudocima salaminia*) cause much damage to lychee and longan by piercing the skin of ripening fruit and sucking out the juice. No chemical control is available for these large nocturnal moths, although nets with a mesh of 15 to 20 millimetres will effectively exclude them. These nets will also exclude birds and flying foxes. A smaller mesh with a cross hair would also keep out some macadamia nutborer and elephant beetles. These cost from $15,000 to $25,000 per hectare. Check with netting suppliers in your area.

Harvest, handling, packaging, storage and post-harvest treatments

For lychee, the season commences with cultivars Fay Zee Siu in northern Queensland in November and finishes with cultivar Wai Chee in northern New South Wales in March. For longan, fruit are available from late January (cultivar Kohala) until early April (cultivar Haew) in the same regions. At any one location, harvesting normally lasts about six weeks with a spread of cultivars.

Neither fruit ripen off the tree, so they must be picked mature. For lychee, maturity is indicated by a minimum brix:acid ratio of 35:1, although ripe fruit generally have a much higher ratio. Maturity of lychee is judged by the shape, size, color and flavor of the fruit, which varies greatly with cultivar. Normally, longan fruit can be judged by fruit size and flavor. Both crops become bland if picked over mature.

Fruit should be harvested early in the morning before they warm up. Some growers pick early season fruit individually off the panicle (spot-picking), however, generally the bulk of the crop is picked in clusters. There is strong demand for longans on branches and branchlets in some markets.

Once lychees are picked, they start to dry out and brown Fruit should be kept in a high humidity and cooled to 5^{o}C as quickly as possible. Hydrocoolers or cool rooms are frequently used for this purpose. Untreated longan fruit suffer chilling injury and loose flavor below 9^{o}C, but do not brown as quickly as lychee.

After picking, fruit are destalked and sorted visually on mechanical conveyors to remove small, poorly colored or damaged specimens.

Industry quality standards have been developed for lychees, but there are none available for longan. For lychee, Extra class must be practically free of defects, and typically comprises no more than 10% of the crop. First class fruit can have moderate defects with skin blemishes not exceeding 60 square millimetres in total on any one fruit. Other standards operate for other segments of the industry who have a commitment to quality assurance and are members of the United Lychee Marketing Association (ULMA).

To reduce water loss and browning, lychee fruit are marketed in bulk packages in nine litre cartons which hold 5 kg of fruit and packed in two 2.5 kg low density polybags. Fruit can also be packed in 250

g punnets, with a cling wrap film. Longans are generally marketed in bulk packages including non-recyclable plastic crates. Both fruit should be free of surface moisture before being packed to reduce the potential for disease development.

Fruit are normally shipping by refrigerated transport. This system retains the red skin color in lychee and greatly prolongs shelf life in both crops. However, once the retailers open the bulk packs, fruit begin to deteriorate under air conditioning in the stores.

In Thailand, longan fruit (on branchlets) are treated with sulphur dioxide, packed in 10 kg plastic crates, cooled to 2° to 5°C, and cool transported to Bangkok for sea or air freight to Hong Kong, Singapore and Indonesia where they have a shelf life of up to six weeks. There is temporary board approval of this treatment in Australia which substantially reduces the incidence of post-harvest rots and off-flavours which may develop in cool storage.

Fruit are sold at the farm gate, consigned to the wholesale markets in Brisbane, Sydney or Melbourne or exported. You can handle marketing yourself or join one of the lychee marketing groups. If sending fruit to some of the southern markets quarantine restrictions must be adhered to. These restrictions vary from season to season.

Economics of production

At least $150,000 is needed to set up a viable seven hectare lychee farm to purchase basics such as a tractor, sprayer, slasher, small farm shed, irrigation and tree establishment. This does not include the cost of land. A further $150,000 would be required for netting, picking and packing (including a cold room) once the trees started to bear. Similar costs are associated with setting up an equivalent longan enterprise.

Yields vary widely with cultivar, season and location, from about 10 to 100 kg per tree at year ten. Average yields would be expected to be about 5 kg per tree at year five rising to about 50 kg per tree at year ten. Longans are slightly more productive, especially on the Atherton Tableland in northern Queensland.

Prices also vary greatly with cultivar, season and quality, from about $2 to $12 per kg. Average prices are about $4 to $5 per kg for lychee, and slightly higher for longan

Gross margins have been calculated for lychees on the Atherton Tableland in northern Queensland. With a yield of 55 kg per tree and a planting density of 140 trees per hectare (7.7 tonnes per hectare), estimated gross margin (income minus variable costs) was about $21,570 per hectare. These figures assumed that 50% of fruit were sold as first class at $6 per kg, 40% as second at $5 per kg and 10% at the farm gate at $4 per kg.
The gross margin is very sensitive to price. With 50 kg per tree, it is $20,060 at $5.40 per kg and only $9,048 at $3.60 per kg. Further details of the economics of growing lychees and longans can be found by contacting the Queensland Department of Primary Industries at Mareeba.

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About the authors

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Dr Cameron McConchie is Principal Scientist with the CSIRO Division of Plant Industries at St Lucia in Brisbane. Dr McConchie has studied the breeding system of lychees for the past ten years.

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Source

Menzel, C. M. and McConchie, C. A. (1998). Lychee and longan. In *The New Rural Industries* (K. W. Hyde, Ed.). Rural Industries Research and Development Corporation, Canberra. pp. 288-95.

APPENDIX 4

LOOKING AFTER YOUNG TREES

Young trees need regular care. Appropriate fertilising, irrigation, tree shaping and pest control will produce a healthy and productive tree.

Fertilising

During the first three years, fertilisers are used to produce maximum tree size. After planting, trees will not need any fertiliser until they produce their first leaf flush.

Rates and timing of applications are outlined below. In frost prone areas don't apply fertiliser during autumn or winter. Do not exceed the recommended rates. Excessive amounts of either organic or inorganic fertilisers can cause tree death, especially on shallow, poorly drained soils. Keep fertilisers at least 20 cm away from the trunk to avoid burn. Apply fertiliser evenly under the canopy and out to a point 30 cm past the dripline. Water in well or apply during rain.

Fertiliser program for the first four years (rates per tree)

Timing	Product	Year 1	Year 2	Year 3	Year 4
Every month	Urea	30 g	40 g	60 g	80 g
Every three months	Fertica or similar	30 g	40 g	60 g	80 g
Spring	Millmud or		25 L	35 L	
	fowl manure		8L	15 L	

Irrigation

Timing and quantity of water varies with tree size, tree vigor, soil type, weather conditions and time of year. The following table offers a guide based on evaporation conditions in south Queensland. Some areas in Nicaragua may be drier.

Irrigation rates for young tees (litre per tree per week)

Tree age	Canopy diameter (m)	Winter	Spring	Summer	Autumn
1 year	0.5	3	6	8	5
2 years	1.0	12	24	32	20
3 years	1.5	30	60	80	50
4 years	2.0	60	120	160	100

Irrigate two to three times a week for sandy soils and one to two times a week for heavy clay soils.

Pruning and branch support systems

Young lychee trees are pruned to provide a strong tree structure, to minimise wind damage and to increase the fruit bearing area. The Table below details growth habits and wind damage susceptibility for the major cultivars.

Growth habit and wind damage susceptibility

Variety	Tree vigor	Tree shape	Type of branches	Type of foliage	Susceptibility to limb breaking	Susceptibility to twisting
Fay Zee Siu	high	spreading	long	dense	high	low
Tai So	high	spreading	long	dense	high	low
Bengal	high	spreading	long	dense	medium	medium
Haak Yip	medium	spreading	v. long	open	high	low
Kwai May Pink	medium	erect	long	dense	high	low
Wai Chee	low	dome	short	v. dense	low	high

Pruning

Trees should be inspected regularly during the first four years and the following action taken where necessary. Remove branches with weak, narrow crotch angles where the bark is folded into the crotch. On susceptible cultivars such as Tai So and Kwai May Pink, these branches can later split away from the trunk causing severe damage. Don't remove branches until trees are 12 months old.

Tip prune cultivars which produce long branches or dominant leader branches, for example, Tai So and Kwai May Pink. Remove approximately 15 cm in the spring of the second year. This increases the number of growing points which means more flowers and fruit. The risk of a major limb breakage is also reduced.

Thin out very dense cultivars such as Wai Chee and Kwai May Pink. Remove approximately 10% to 20% of the branches within the canopy after the first year. You should be able to see broken sunlight on the ground under the tree when you have finished. This practice allows wind to move through the tree and reduces the risk of the tree twisting out during heavy winds. Checks and repeat each year if necessary.

Skirt trees from the second year onwards by removing all branches and shoots to a height of 50 to 60 cm leaving a clean single trunk. Skirting also helps minimise the twisting effect of high winds and prevents fruit and leaves touching the ground. This allows orchard activities such as slashing, herbicide and fertiliser application to be carried out efficiently, without damage to trees. Loss of fruit to insects and rots is avoided. Ant and scale control is made easier.

Branch Support

In spite of your best pruning efforts, some cultivars such as Tai So will still produce weak crotches which are likely to split. To minimise this risk growers have devised a strapping and bracing system using heavy gauge wire to link the main branches.

I. Pests

The most important pest of young trees is erinose mite. Symptoms are blistering of the leaf surface and brown felting on the underside. If not controlled it can cause severe damage to trees and greatly reduce flowering and fruit production.

The best control is to prevent it entering your property by dipping trees at purchase as already indicated. If you do find symptoms in your trees, early adoption of the following program should eradicate the problem:

- Remove and burn infested leaves. If most are infested, removal is impractical.
- Spray each new growth flush with dimethoate or wettable sulphur every 10 to 14 days, from just before the flush emerges until it hardens off. Repeat for each new flush. Stop spraying once the problem is under control. Sulphur is the least disruptive to beneficial insects and is preferred except when temperature are above 24°C.

Occasional pests of young lychee trees include scales, leaf eating caterpillars, leaf eating beetles and twig girdlers. Control measure are listed below.

Borers can sometimes attack trees but no practical control exists. Individual branches may die back, but whole trees are rarely lost.

Pest control for young lychee trees

Pest	Active ingredient	Some commercial products	Rate per 100 L	Withholding period (days)	Comments
Erinose mite	dimethoate	Rogor 400 Perfekthion 400	75 mL	7	Don't spray during flowering.
	or wettable sulphur	various available	300 g	0	Don't use in temperatures above 24°C. Thorough coverage essential.
Leaf eating insects & twig girdlers	carbaryl	various available	125 g or 200 mL	3	Only spray when insects active or damage has occurred.
Scale	methidathion + white oil	Supracide 400 + Lovis	125 mL + 1 L	14	Apply only if scale build up occurs. Clean up weeds around trees and spray for ants.
Ant	chlorpyrifos	Lorsban 500	200 mL	14	Apply to trunk and ground under tree up to twice a year.

Diseases

Lychee trees are generally not subject to any major diseases. Young trees are occasionally lost to 'sudden death' syndrome. No disease organism has yet been shown to cause this problem. Sudden death rarely occurs where proper land preparation steps have been followed. The main points are: only plant on well drained soils, plant on mounds and avoid root damage from careless planting or over-fertilising.

Weed control and mulching

Weeds compete with trees for water and nutrients. If allowed to grow large, considerable tree root damage can occur when the weeds are eventually removed. Major weed problems are avoided by maintaining a mown sward of mixed grasses and broadleaf species between the rows. Weeds under the trees are controlled by mulching and spot spraying with herbicides.

Mulches used include wheat or barley straw, hay, sorghum stubble and similar materials. Reduce costs by growing mulch material between the rows for later slashing. Renew the mulch as it breaks down. Keep it well away from the tree trunks as collar rots may develop. Mulches also increase soil organic matter, improve soil structure, increase water retention and reduce root temperature fluctuations.

Apply herbicides to the border of the mulched area and to individual weeds which grow through the mulch. Use one of the following to control grasses and broadleaf weeds:

- glyphosate (Roundup or Glyphosate) at 5 to 10 mL/L of water
- paraquat (Gramoxone) at 1 to 6 mL/L of water plus a wetter at 1.25 mls/L of water.

For grass control only use fluazifop-p (Fusilade 212) at 1.25 to 10 mL/L.

Don't allow herbicides to contact any green part of the tree, including the trunk. Drift can be minimized by using a shielded, low-pressure fan or flood nozzle. Alternatively, use a rope wick applicator.